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THE SOILS OF AUSTRALIA

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NATURE AND DEVELOPMENT OF AUSTRALIAN SOILS

The soils of Australia constitute one of her greatest natural resources. Spread over a continent of nearly 3,000,000 square miles, of which approximately one-third lies within the tropics, they include soils developed on a wide range of rock types and under climatic conditions varying from the alpine zones of south-eastern Australia and Tasmania, through the Mediterranean zones of southern and south-western Australia and the wet and dry tropics of Queensland, to the very low rainfall areas of the centre.

Australia provides two features which distinguish it from the continents of the Northern Hemisphere, where the scientific study of soil developed and where most investigations have been made. In the first place, the biological components of the environment in which Australian soils developed were widely different from those encountered elsewhere. The dominance of eucalypt and acacia species in the vegetation, the absence of modern herbivores from the native fauna, and the fact that the Aboriginal Australian did not cultivate the soil mean that, since British settlement commenced 177 years ago, the soils have been progressively exposed to biotic influences widely different front those under which they formed, and with which they were approximately in equilibrium. That the soils are changing or have changed under the impact of these new factors is often obvious, and the extent to which they are eroding shows that new equilibria have not yet been achieved.

In the second place, the great proportion of Europe and of North America were stripped of their former soils by the ice-sheets of the Pleistocene age, and soil formation started anew on fresh rock surfaces or on the deposits of fluvo-glacial transport about 10,000 years ago. By contrast, in Australia, apart from the very small areas that were glaciated in the south-east and Tasmania, or the much larger areas of Pleistocene and Recent alluvia, the soils have been formed on land surfaces that have been continually exposed to weathering, probably since the late Tertiary age. Ancient and deeply weathered profiles * are consequently a widely distributed feature of the Australian landscape. They dominate the soil pattern in many areas, and by virtue of the intense weathering to which they have been subjected they pose problems in plant nutrition that are not

encountered in younger soils. The nature and distribution of the present day soils in many areas is consequently closely related to the geomorphology, which reflects the manner in which the land surface has been sculptured by erosion and deposition.

The result depends on whether the land surface maintains its ancient form, or whether it has subsequently been dissected. When little or no dissection is occurring, the soils of the old land surface remain, strongly leached and deeply weathered, and in the drier regions quite out of harmony with the present climate. In this category are the arid red earths of the centre, the soils of the Cobar peneplain in New South Wales and the broad divide north of Clermont in western Queensland.

Where dissection is occurring, the influence of the old land surface is most marked where weathering had produced a laterite. Laterite profiles have a massive or concretionary horizon in which oxides of iron and aluminium are concentrated, overlying a kaolinized zone which is commonly bleached - the so-called pallid zone, which in turn overlies an horizon which is largely kaolinized, although still maintaining the form of the parent rock. If the old top soil is still present, it will be white or light-coloured sand or loam on acid rocks such as granite, or red, friable and granular clay on basic rocks such as basalt. Since the depth to unweathered rock commonly exceeds 70 feet and may reach 1 75 feet, the surface soil found at present depends largely on which horizon of the laterite has formed its base, and on the extent to which other horizons have contributed. As a result, a characteristic pattern of soils is associated with the lateritic residuals. Agricultural development of these soils has not been possible until comparatively recently because of extreme deficiencies of phosphorus, potassium and nitrogen, and widespread deficiencies of the minor elements copper, zinc, molybdenum, and manganese.

Agricultural development of Australian soils

In general, the productivity of Australian soils is largely determined by the moisture supply. On only about ten per cent of the continent is natural rainfall sufficient, or excessive, for plant growth for nine to twelve months of the year, and some of this falls or drains on to soils too steep and stony, or too elevated and cold. However, many swamps and fens and several areas of excessively wet podsolic and rendzina soils have been rendered highly productive by drainage and the use of appropriate fertilizers.

Where moisture is continuously or seasonally abundant, but not excessive, in the southern parts of the continent, productivity is governed largely by the almost universal need for phosphatic fertilizer. There is also a widespread need for sulphur, which has often been masked by the large content of gypsum present in the form of superphosphate that has been used. The need for potassium is increasing. In these regions the yields of crops and sown pastures are normally increased severalfold by the use of superphosphate, aided as necessary by trace elements. On several soils a large increase with the use of fertilizers is also obtained in plantations of **Pinus radiata** and other tree species.

Where similar moisture conditions occur in tropical and sub-tropical areas, as in coastal Queensland and northern New South Wales, the pattern of production is dominated by sugar-cane, but sown pastures are increasing in importance. Here phosphatic, potassic and nitrogenous fertilizers are used, and yields are high. In areas of rather lower rainfall, cane production is assisted by irrigation.

Where seasonal rainfall is of shorter duration and not so reliable, as in much of the wheat-growing area, the rhythm of agricultural production is synchronized with this. In general, yields of crops and the carrying capacity of the associated pastures in the rotation are dependent on the use of superphosphate, except in some areas of black earths in southern Queensland and northern New South Wales.

Because of low and unreliable rainfall, no arable agriculture or sown pasture production is possible over much the greater part of Australia. In these arid to semi-arid regions pastoral activities at low carrying capacity are all that can be expected. Production is so limited by low soil moisture that there would appear to be no economic place for fertilizers. The surface and underground water resources of the area are so low or so saline that little development of irrigation is possible.

***** A section through the soil showing the different horizons (see + below) or layers which extend downwards from the surface to the parent material.
+ Plane of stratification assumed to have been once horizontal and continuous.

TYPES OF AUSTRALIAN SOILS

Stony and shallow soils

A large part of the Northern Territory and of the northern part of Western Australia, exceeding 400,000 square miles in area, is covered by rocky country almost devoid of soil. Such soil as occurs is usually shallow, leached and mildly acid, and of generally low fertility. It is probably incapable of development and provides only sparse grazing for cattle.

Soils of the alpine and perhumid zones

These soils include the high moor peats and alpine humus soils of the Australian Alps and Tasmanian highlands and the peaty podsols of the cold perhumid western region of Tasmania. The characteristics common to them are highly organic surface horizons, extreme acidity, and excessive moisture supply. No form of arable agriculture is undertaken, not only because of the above-mentioned properties, but also because of their unsuitable climate and rugged terrain. To a large extent the soils are mixed with much exposed rock and are themselves often excessively stony.

Of these soils the alpine humus soils are forested in part, and some timber is extracted. However, the commonest form of land use on all or them has been the seasonal grazing of sheep and cattle, stock being moved on to them in late spring and removed to lower and more hospitable areas in autumn. Because of their abundant rainfall and seasonal snow cover both the Australian Alps and the Tasmanian highlands have progressively become the scene of major engineering enterprises connected with water storage. The objectives are the development of electric power and the regulated supply of water for irrigation of lands outside the mountain regions themselves. These projects have brought a re-appraisal of the long-term value of seasonal grazing and its effects on the alpine vegetation. These arise from ancillary practices such as burning to stimulate new growth of greater palatability to stock. As a consequence there has been some erosion damage to the landscape. Engineering works themselves, such as roads and channels, have also brought problems of landscape stability in their train. Techniques to combat these are being developed. Meanwhile there is a trend towards the stricter control or elimination of the trans-humance, or seasonal moving, of stock in an effort to conserve the alpine areas for their most valuable long-term national use, the conservation and regulation of water.

Soils of the humid zones

Leached soils. Under this heading are grouped the acid soils of the moderately humid regions where, because of perennially or seasonally abundant moisture, sown pastures and arable agriculture arc widespread. These soils also carry the bulk of the useful natural forests of Australia and include the majority of the areas devoted to plantations of exotic and indigenous species. The **acid swamp soils** with their more or less peaty surfaces, although restricted in area, are widely exploited with the aid of artificial drainage. Together with much smaller areas of

neutral to alkaline fen peats, they are devoted mainly to sown pastures and vegetable production. They reach their highest level of productivity in the drained and irrigated swamps of the lower Murray Valley, where carrying capacity exceeds a milking cow to the acre.

Podsols, usually sandy, have a bleached subsoil overlying an organic and ferruginous pan. This pan may be so indurated that root penetration is difficult and temporary water-tables form above it. The most extensive areas of these soils are on the coastal plains or south-western Australia, southern Queensland, New South Wales, and the large sand islands of the southern Queensland coast. Their coarse texture and poverty in all nutrients has caused them to be neglected until recently. In Queensland, with heavy use of fertilizers, it is possible to develop good pastures. In southern Australia plantations of the exotic trees **Pinus radiata and Pinus pinaster** give responses to zinc, phosphorus and nitrogen.

The **podsolic soils**, formed on finer textured or less siliceous rocks, have a clay subsoil beneath sandy to loam surface soils. These soils are more widespread than the podsols, and are generally less acid. Practically universal responses to superphosphate, and very frequent responses to one or more of the trace elements, copper, zinc, molybdenum, and boron, have been obtained. The most extensive use of the podsolic soils has been for pastures based on subterranean clover, usually top-dressed annually with superphosphate. This form of land use has increased Stock carrying capacity severalfold and built up soil fertility to the stage where increasing use is being made of arable crops, such as potatoes and cereals, to take advantage of the enhanced nitrogen status. After a protracted period of use, the podsolic soils exhibit an uneven incidence of potassium deficiency, but the correction of this is straightforward once it has been recognized. These soils are used for horticultural purposes, particularly for pome fruits, and for forest plantations, especially of **Pinus radiata**. In more northerly areas some sugar cane is grown on them.

Krasnozems, deep friable red clay soils, often strongly acid, are found mainly on the volcanic rocks which have a scattered distribution in the eastern States. The krasnozems were originally densely forested, but, with little proper exploitation of their timber resources, these soils were rapidly cleared and converted to intensive forms of agriculture ranging from perennial pastures and temperate fodder crops, vegetable and grain crops in southern areas, to sugar, maize, peanuts, and some sown pastures in tropical and sub-tropical localities. The initial fertility of the soils has declined rather rapidly, and they have a restricted response to superphosphate due to a high rate of reversion of phosphorus to less available forms. They respond widely to molybdenum and, over increasing areas, to potassium. Despite their limitations, however, including a somewhat difficult fertilizer economy, these soils retain their position amongst the most productive in Australia.

Red earths and **yellow earths** are associated with old land surfaces, sometimes forming divides, sometimes prominent mesas and sometimes broad terraces. They have brown, grey or red brown surface horizons merging into red or yellow, massive, but porous, subsoils, mainly acid at the surface and normally becoming more acid with depth. They are of low inherent fertility, markedly deficient in phosphorus, nitrogen and trace elements, but responding well to good management. Where they are located favourably in relation to markets. a wide range of crops is grown on them, e.g. tropical fruit and vegetables near Brisbane, and sugar cane in coastal country.

The **chocolate soils** occur mainly on basalt on the tablelands of New South Wales. They are brown soils with a friable clay surface horizon overlying a tighter clay subsoil, with floaters of parent rock throughout. Only moderately acid on the surface and becoming neutral with depth, they present few problems, respond readily to fertilizers, and are intensively farmed for perennial pastures and such vegetable crops as potatoes and peas.

Soils on calcareous materials. Shallow, neutral to alkaline soils resting on limestones can be

either red - terra rossas - or black - rendzinas. The terra rossas are variable in texture, but the rendzinas are generally well structured clay soils, some having seasonally rising and falling groundwater.

The only extensive occurrence of rendzinas is in the south-east of South Australia, where they occupy the wet calcareous floors of long swales between ridges of ancient stranded coastal dunes. These soils have been extensively drained and developed, and are now mostly devoted to pastures. They respond to superphosphate and, variably, to the trace elements copper, zinc and manganese.

Terra rossas, which are well drained shallow soils, are often so stony or intruded by so much outcropping limestone that their usefulness is frequently very limited. The largest aggregate area is on the better drained positions in association with rendzinas in the south-east of South Australia. They are most frequently used for pastures, either natural or sown, and, where deeper, for vines and stone fruits.

Soils of the seasonally humid zones

In these climatic zones the rainfall is sharply seasonal, with a winter incidence in the south and a summer incidence in the north. In the latter it is also erratic. The soils fall into five main groups, the red-brown earths, black earths (or chernozems), solodic soils, red and yellow earths, and lateritic podsolic soils.

The **red-brown earths** have developed commonly on slates, shales and granites and on areas of old alluvium that are now above the level of modern floods. They have brown to grey brown, loam to sandy-loam, surface soil overlying a reddish-brown clay subsoil. The surface soil is mildly acid, but the acidity diminishes with depth and concretions of calcium carbonate are present in the deeper layers. The organic matter is concentrated in the surface soil, and where this has been lost by erosion fertility falls. The soils are well supplied with potassium, calcium and magnesium, but are always deficient in phosphorus and nitrogen. They are widely used for cereal production in the winter rainfall regions of southern Australia, and in New South Wales and Victoria have been extensively irrigated for pasture and horticultural production.

The **black earths** or **chernozems** are black or dark brown in colour and clay in texture, with a good granular structure in the surface soil which becomes cloddy and massive in the deeper layers. They are usually slightly acid to neutral in the surface, becoming neutral to alkaline with depth, with an horizon of calcium carbonate concretions at varying levels from eight inches to three feet below the surface. These occur on either side of the Eastern Divide from central Queensland to Tasmania. Those in northern New South Wales and Queensland have areas where the surface soil is alkaline. All Australian soils in this group differ from their counterparts in Europe and north America in containing less organic matter, which falls with diminishing rainfall and increasing temperatures, and they are usually heavier in texture. On drying out these soils crack widely and deeply, and on wetting become very sticky. Prior to cultivation they show **gilgai** (**see below**) micro-relief. These are the most fertile arable soils in Australia, and are unique in the high levels of available phosphate they contain. They are also relatively rich in nitrogen, and, unlike the red-brown earths, the organic matter is distributed through the top two or three feet of soil. The addition of sulphur as fertilizer is sometimes necessary, and responses to zinc are obtained. Where they are formed on alluvium or on parent materials low in phosphorus they may also respond to phosphate. Rotations in the northern summer rainfall areas are more varied than in the south, and include wheat, sorghum and lucerne, linseed, safflower, millet, and maize. Many farmers grow wheat continuously for several years. using a short summer fallow to conserve the summer rainfall for the winter growing crop. Only a small part of these soils is irrigated, but this includes the high producing cotton growing areas irrigated from the Namoi River. Arable development of these soils was originally restricted because cultivation is only possible over a very narrow moisture range and consequently only became an economic possibility with the use

of tractors sufficiently powerful to complete the necessary cultivation in the limited time available.

The **euchrozems** of northern New South Wales and Queensland are formed on the deeply weathered lower horizons of ancient laterites formed on basalt. They have a friable dark brownish red clay loam at the surface, merging into blocky structured orange to orange-yellow clay, with decomposing basalt at depths of four feet or deeper. They differ from the chernozems mainly in containing more free ferric oxide, and they do not crack so widely. Agriculturally their properties are similar to the chernozems but they are generally lower in available phosphate, although they respond well to superphosphate.

The solodic and solodized - solonetz soils occur in all States and are particularly extensive in the sub-coastal regions of Queensland, where they form the bulk of the spear-grass country. They have commonly formed on old alluvial deposits and on a wide range of rocks. The soils have a grey sandy to loamy surface, moderately to strongly acid in reaction, sharply differentiated from a mottled yellow, brown, orange, and grey dense clay subsoil. The subsoil may exhibit a strong prismatic structure with well-marked flat topped columns at the junction with the surface soil. Usually in the lower horizons the acidity falls, and in some cases calcareous concretions are present. In their natural state these soils are very infertile, and are deficient in nitrogen and phosphorus as well as trace elements. Although commonly containing concretionary calcium carbonate in the deep subsoil, the calcium levels of the surface soil are often so low as to be deficient for such shallow rooting plants as the introduced pasture species. Deficiencies of potassium occur in many areas, and molybdenum deficiency is widespread. Their development, which has so far only been undertaken in limited areas, requires the rectification of these deficiencies and the introduction of a suitable legume.

The **lateritic podsolic soils** have light coloured sandy horizons over a concretionary ironstone horizon over mottled or white leached clay. They are mildly to strongly acid throughout and are strongly weathered and leached. They usually occur on ancient lateritic land surfaces. Extensive areas of these soils occur in north Australia, in south-western Western Australia and in South Australia, In the natural state they carry heath vegetation and low mallee. They are extremely deficient in phosphorus and nitrogen, as well as in trace elements. However, clearing costs are low, and in the winter rainfall areas of Western Australia very considerable areas of these soils are now being developed for improved pastures, with blue lupin or subterranean clover as the pioneer crop.

Soils of the semi-arid zones

The major soils of the semi-arid zones include the highly calcareous solonized brown soils restricted to southern Australia, the massive structured, variably calcareous and gypseous grey and brown soils of heavy texture, and the red earths of the old land surfaces.

The **solonized brown soils** lie largely in a zone of low rainfall, approximately 9 to 15 inches per annum of unreliable, winter incidence. They are deep sandy to shallow loamy soils overlying deep rubbly and powdery caleareous clay subsoils, and are neutral to alkaline at the surface, becoming more alkaline with depth. Their landscape is frequently characterized by a parallel east-west dune system. These soils make up a large part of the low yielding wheat lands of southern Australia. They are farmed on a wide rotation, comprising volunteer pasture-fallow-wheat, in which superphosphate is used solely with the wheat. Sheep graze the pastures. These soils, especially the sands, are very susceptible to wind erosion, and much effort is now devoted to the stabilization of the once cleared and cultivated dunes. The common plant for reclamation is cereal rye. Where the solonized brown soils lie adjacent to the Murray River they are widely irrigated, especially for horticultural production, principally of grapes and citrus fruits. Under skilled management they are very productive, but are liable to rising groundwater and secondary salinity problems where drainage is inadequate.

The **grey and brown soils of heavy texture** are uniform clays, ranging from grey to brown and becoming mottled with depth. They are slightly acid, neutral or slightly alkaline at the surface, becoming moderately to strongly alkaline with depth. Gypsum is often present in the subsoils, and excessive salinity may occasionally be a problem. They occur on alluvial deposits of Pleistocene and Recent age as well as on contemporary alluvium, and on sedimentary rocks of varying ages, in a great are from the south-east of South Australia through eastern Australia to the Barkly Tableland in the Northern Territory, with smaller outliers in the Kimberleys. In Queensland and northern New South Wales considerable areas carry a tall scrub of brigalow (**Acacia harpophylla**). Where this occurs on old alluvium more than half the soils show the unusual feature of having a neutral to alkaline surface soil overlying a strongly acid subsoil. They are generally of moderate fertility, but the phosphorus contents are very variable. On the wetter fringe, as in the Wimmera district of Victoria and the Namoi and Macquarie regions of New South Wales, these soils are used for wheat growing. In Queensland, with moisture conservation by bare fallowing, a wide range of summer and winter crops can be grown. Elsewhere they make up a high proportion of the better natural pasture lands used for cattle and sheep grazing. Where they occur in the irrigation areas of the Murrumbidgee and Murray rivers in New South Wales and Victoria their low infiltration rate poses some difficulties in the irrigation of pastures but makes them particularly suitable for rice. Most of the soils are gilgaied (**see below**) to some degree, and strongly so on the wetter fringes.

Red earths associated with old land surfaces are widely distributed throughout the semi-arid areas, and constitute a major component of the wool-producing lands of south-west Queensland and north-west New South Wales, as well as larger areas of the Northern Territory. They are usually covered with scrub and are practically unused for agriculture. They are generally devoted to sheep and cattle grazing.

Soils of the arid zones

The soils of the arid zones fall into three broad categories:

(a) those that are coarse-textured enough to be moved by wind action - the desert sandhills and desert sand plains;
(b) those that resist wind action - the arid red earths, the desert barns and the stony desert soils; and
(c) the calcareous desert soils of the Nullarbor Plain.

The **desert sandhill country** is covered by long parallel sand ridges separated by inter-dune corridors ranging from *25* feet to a half a mile wide. In general the whole surface from dune crest to swale is covered by deep sandy soils, mildly acid throughout, usually bright red brown. The desert sandplains have similar soils on a very gently undulating landscape. These areas carry spinifex and some shrubs and are mainly useless for grazing. At slightly higher rainfalls on the South Australian-New South Wales border the inter-dune corridors are covered with grey clay or loam of varying depth and covered with roughly octagonal cracks in their normal dry state. After the occasional rain storms these areas are briefly flooded. The dune corridors carry grass, but over considerable areas the flanks of the dunes carry a scrub of drought resistant shrubs with mulga **(Acacia aneura)** as the principal component.

The finer textured soils, the **arid red earths**, the **desert barns** and the **stony desert soils** differ in texture from each other and in the degree of profile development, but are all red-brown to brown in colour. They make up a large proportion of the country utilized for grazing. The vegetation includes grasses and edible shrubs such as mulga on the arid red earths and shrub steppe on the desert loams. The stony desert soils carry a layer of stones on their surface and are almost treeless.

The **calcareous desert soils** are shallow powdery caleareous soils, sedentary on limestone.

They are covered by a shrub steppe and are particularly susceptible to wind and water erosion, especially where their vegetative cover has been reduced by overgrazing.

The gilgai phenomena

This feature, which is widely developed throughout the heavier soils, consists of small-scale undulations of the land, the alternate hummocks and hollows of which show some degree of regularity. They have been called variously ‘gilgai’, ‘crab-hole’, ‘melon-hole’, and ‘Bay of Biscay country’. Considerable differences in magnitude and form of the undulations occur, and since the different names are not applied consistently to any one form, the term ‘gilgai’ is now used for all manifestations. They all show a characteristic swelling pattern on wetting, the subsoil swelling more than the topsoil. Originally described in Australia, this phenomena has subsequently been recognized in many other countries where a suitable combination of soil and climate exists.

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